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0518252.2 under Section 15(4) of the Patents Act 1977(71) Applicant(s):
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(continued on next page)

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WO 2005/088070 A1 US 3785193 A
US 2627891 A(58) Field of Search:
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(54) Abstract Title: Apparatus and method for radially expanding a wellbore casing using an expansion mandrel and a rotary expansion tool

(57) An apparatus for radially expanding and plastically deforming a tubular member, comprises a first expansion device 104 for radially expanding the tubular member; a second expansion device 108 coupled to the first expansion device for further radially expanding the tubular member; and a motor 106 coupled to the first expansion device for at least one of: rotating the second expansion device 108 relative to the first expansion device 104, and/or displacing the second expansion device 108 relative to the first expansion device 104.

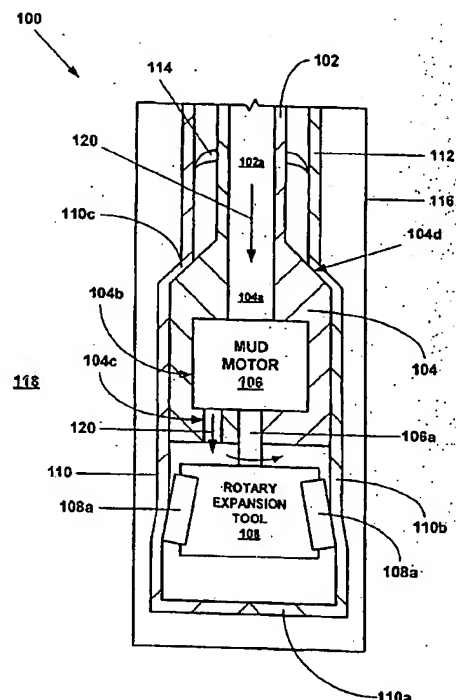


Fig. 1

GB 2427886 A continuation

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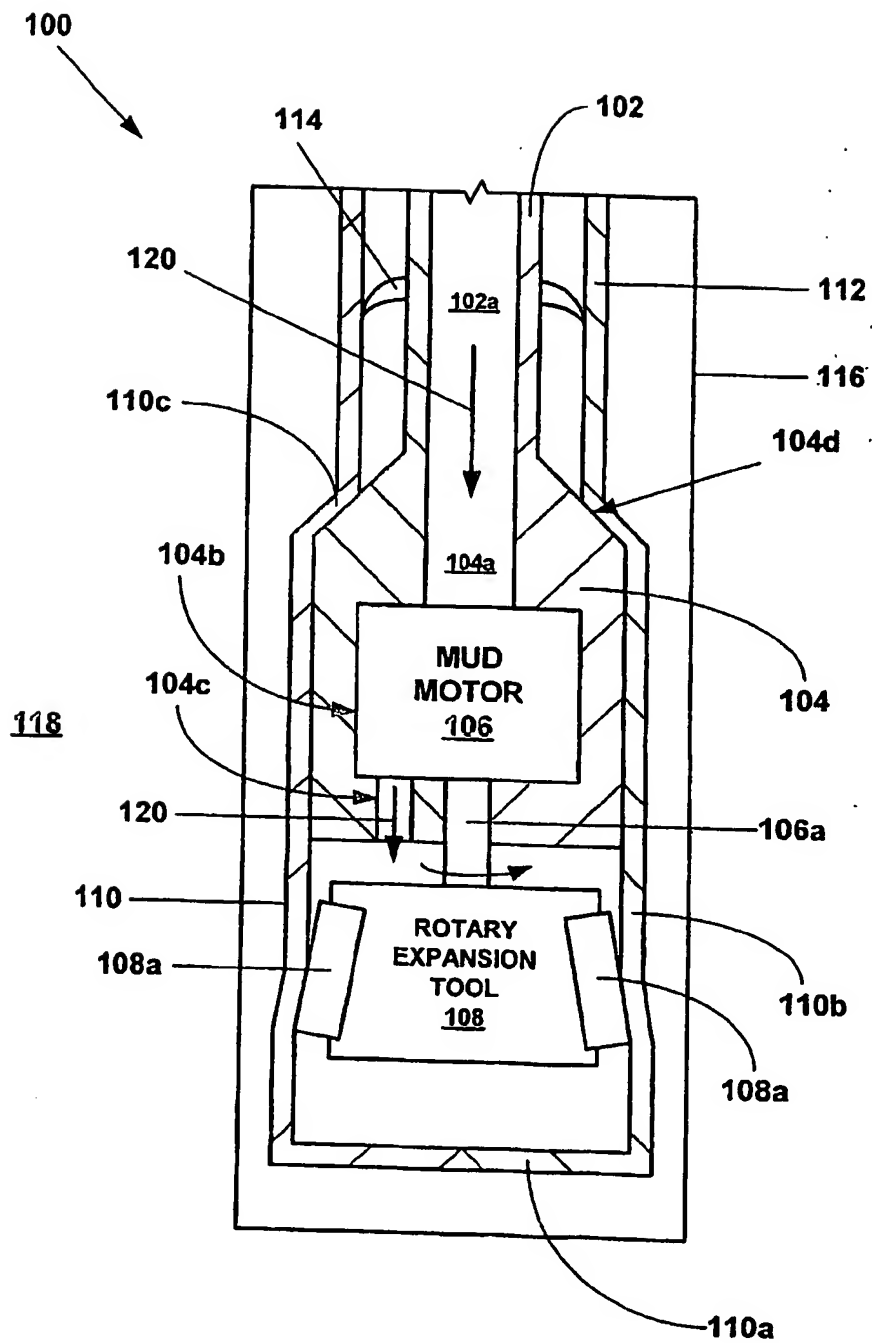


Fig. 1

**APPARATUS AND METHOD FOR RADIALY EXPANDING A WELLBORE CASING
USING AN EXPANSION MANDREL AND A ROTARY EXPANSION TOOL**

Cross Reference To Related Applications

The present application claims the benefit of the filing date of U.S. provisional
5 patent application serial no. 60/454,896, attorney docket no. 25791.236, filed on March
14, 2003, the disclosure of which is incorporated herein by reference.

The present application is related to the following: (1) U.S. Patent Number
6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney
docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional
10 application 60/111,293, filed on 12/7/98, (2) U.S. patent application serial no.
09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, which claims priority
from provisional application 60/121,702, filed on 2/25/99, (3) U.S. patent application
serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims
priority from provisional application 60/119,611, filed on 2/11/99, (4) U.S. patent no.
15 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338,
attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from
provisional application 60/108,558, filed on 11/16/98, (5) U.S. patent application serial
no. 10/169,434, attorney docket no. 25791.10.04, filed on 7/1/02, which claims priority
from provisional application 60/183,546, filed on 2/18/00, (6) U.S. patent application
20 serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which
claims priority from provisional application 60/124,042, filed on 3/11/99, (7) U.S. patent
number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney
docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional
application 60/121,841, filed on 2/26/99, (8) U.S. patent number 6,575,240, which was
25 filed as patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed
on 2/24/2000, which claims priority from provisional application 60/121,907, filed on
2/26/99, (9) U.S. patent number 6,557,640, which was filed as patent application serial
no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims
priority from provisional application 60/137,998, filed on 6/7/99, (10) U.S. patent
30 application serial no. 09/981,916, attorney docket no. 25791.18, filed on 10/18/01 as a
continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S.
Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed
on 11/15/99, which claims priority from provisional application 60/108,558, filed on
11/16/98, (11) U.S. patent number 6,604,763, which was filed as application serial no.

09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, which claims priority
 from provisional application 60/131,106, filed on 4/26/99, (12) U.S. patent application
 serial no. 10/030,593, attorney docket no. 25791.25.08, filed on 1/8/02, which claims
 priority from provisional application 60/146,203, filed on 7/29/99, (13) U.S. provisional
 5 patent application serial no. 60/143,039, attorney docket no. 25791.26, filed on 7/9/99,
 (14) U.S. patent application serial no. 10/111,982, attorney docket no. 25791.27.08,
 filed on 4/30/02, which claims priority from provisional patent application serial no.
 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (15) U.S. provisional
 patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on
 10 9/16/1999, (16) U.S. provisional patent application serial no. 60/438,828, attorney
 docket no. 25791.31, filed on 1/9/03, (17) U.S. patent number 6,564,875, which was
 filed as application serial no. 09/679,907, attorney docket no. 25791.34.02, on 10/5/00,
 which claims priority from provisional patent application serial no. 60/159,082, attorney
 docket no. 25791.34, filed on 10/12/1999, (18) U.S. patent application serial no.
 15 10/089,419, filed on 3/27/02, attorney docket no. 25791.36.03, which claims priority
 from provisional patent application serial no. 60/159,039, attorney docket no. 25791.36,
 filed on 10/12/1999, (19) U.S. patent application serial no. 09/679,906, filed on 10/5/00,
 attorney docket no. 25791.37.02, which claims priority from provisional patent
 application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999,
 20 (20) U.S. patent application serial no. 10/303,992, filed on 11/22/02, attorney docket
 no. 25791.38.07, which claims priority from provisional patent application serial no.
 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (21) U.S. provisional
 patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on
 11/12/1999, (22) U.S. provisional patent application serial no. 60/455,051, attorney
 25 docket no. 25791.40, filed on 3/14/03, (23) PCT application US02/2477, filed on
 6/26/02, attorney docket no. 25791.44.02, which claims priority from U.S. provisional
 patent application serial no. 60/303,711, attorney docket no. 25791.44, filed on 7/6/01,
 (24) U.S. patent application serial no. 10/311,412, filed on 12/12/02, attorney docket
 no. 25791.45.07, which claims priority from provisional patent application serial no.
 30 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (25) U.S. patent
 application serial no. 10/, filed on 12/18/02, attorney docket no. 25791.46.07, which
 claims priority from provisional patent application serial no. 60/221,645, attorney docket
 no. 25791.46, filed on 7/28/2000, (26) U.S. patent application serial no. 10/322,947,
 filed on 1/22/03, attorney docket no. 25791.47.03, which claims priority from

provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (27) U.S. patent application serial no. 10/406,648, filed on 3/31/03, attorney docket no. 25791.48.06, which claims priority from provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, 5 (28) PCT application US02/04353, filed on 2/14/02, attorney docket no. 25791.50.02, which claims priority from U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (29) U.S. patent application serial no. 10/465,835, filed on 6/13/03, attorney docket no. 25791.51.06, which claims priority from provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, 10 filed on 1/17/2001, (30) U.S. patent application serial no. 10/465,831, filed on 6/13/03, attorney docket no. 25791.52.06, which claims priority from U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (31) U.S. provisional patent application serial no. 60/452,303, filed on 3/5/03, attorney docket no. 25791.53, (32) U.S. patent number 6,470,966, which was filed as patent application serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as 15 a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (33) U.S. patent number 6,561,227, which was filed as patent application serial number 09/852,026 , filed on 5/9/01, attorney docket no. 25791.56, as a 20 divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (34) U.S. patent application serial number 09/852,027, filed on 5/9/01, attorney docket no. 25 25791.57, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (35) PCT Application US02/25608, attorney docket no. 25791.58.02, filed on 8/13/02, which claims priority from provisional application 60/318,021, filed on 9/7/01, 30 attorney docket no. 25791.58, (36) PCT Application US02/24399, attorney docket no. 25791.59.02, filed on 8/1/02, which claims priority from U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (37) PCT Application US02/29856, attorney docket no. 25791.60.02, filed on 9/19/02, which claims priority from U.S. provisional patent application serial no. 60/326,886,

attorney docket no. 25791.60, filed on 10/3/2001, (38) PCT Application US02/20256, attorney docket no. 25791.61.02, filed on 6/26/02, which claims priority from U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (39) U.S. patent application serial no. 09/962,469, filed on 9/25/01, attorney docket no. 25791.62, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (40) U.S. patent application serial no. 09/962,470, filed on 9/25/01, attorney docket no. 25791.63, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (41) U.S. patent application serial no. 09/962,471, filed on 9/25/01, attorney docket no. 25791.64, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (42) U.S. patent application serial no. 09/962,467, filed on 9/25/01, attorney docket no. 25791.65, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (43) U.S. patent application serial no. 09/962,468, filed on 9/25/01, attorney docket no. 25791.66, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (44) PCT application US 02/25727, filed on 8/14/02, attorney docket no. 25791.67.03, which claims priority from U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, and U.S. provisional patent application serial no. 60/318,386, attorney docket no. 25791.67.02, filed on 9/10/2001, (45) PCT application US 02/39425, filed on 12/10/02, attorney docket no. 25791.68.02, which claims priority from U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001, (46) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (47) U.S. utility patent application serial no. 10/516,467, attorney docket no. 25791.70, filed on 12/10/01, which is a continuation application of

U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application
5 60/108,558, filed on 11/16/98, (48) PCT application US 03/00609, filed on 1/9/03, attorney docket no. 25791.71.02, which claims priority from U.S. provisional patent application serial no. 60/357,372, attorney docket no. 25791.71, filed on 2/15/02, (49) U.S. patent application serial no. 10/074,703, attorney docket no. 25791.74, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as
10 patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (50) U.S. patent application serial no. 10/074,244, attorney docket no. 25791.75, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no.
15 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (51) U.S. patent application serial no. 10/076,660, attorney docket no. 25791.76, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional
20 application 60/121,841, filed on 2/26/99, (52) U.S. patent application serial no. 10/076,661, attorney docket no. 25791.77, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (53) U.S. patent application
25 serial no. 10/076,659, attorney docket no. 25791.78, filed on 2/15/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (54) U.S. patent application serial no. 10/078,928, attorney docket no. 25791.79, filed on 2/20/02,
30 which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (55) U.S. patent application serial no. 10/078,922, attorney docket no. 25791.80, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as

patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (56) U.S. patent application serial no. 10/078,921, attorney docket no. 25791.81, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (57) U.S. patent application serial no. 10/261,928, attorney docket no. 25791.82, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (58) U.S. patent application serial no. 10/079,276, attorney docket no. 25791.83, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (59) U.S. patent application serial no. 10/262,009, attorney docket no. 25791.84, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (60) U.S. patent application serial no. 10/092,481, attorney docket no. 25791.85, filed on 3/7/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (61) U.S. patent application serial no. 10/261,926, attorney docket no. 25791.86, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (62) PCT application US 02/36157, filed on 11/12/02, attorney docket no. 25791.87.02, which claims priority from U.S. provisional patent application serial no. 60/338,996, attorney docket no. 25791.87, filed on 11/12/01, (63) PCT application US 02/36267, filed on 11/12/02, attorney docket no. 25791.88.02, which claims priority from U.S. provisional patent application serial no. 60/339,013, attorney docket no. 25791.88, filed on 11/12/01, (64) PCT application US 03/11765, filed on 4/16/03, attorney docket no. 25791.89.02, which claims priority from U.S. provisional patent application serial

no. 60/383,917, attorney docket no. 25791.89, filed on 5/29/02, (65) PCT application US 03/15020, filed on 5/12/03, attorney docket no. 25791.90.02, which claims priority from U.S. provisional patent application serial no. 60/391,703, attorney docket no. 25791.90, filed on 6/26/02, (66) PCT application US 02/39418, filed on 12/10/02, attorney docket no. 25791.92.02, which claims priority from U.S. provisional patent application serial no. 60/346,309, attorney docket no. 25791.92, filed on 1/7/02, (67) PCT application US 03/06544, filed on 3/4/03, attorney docket no. 25791.93.02, which claims priority from U.S. provisional patent application serial no. 60/372,048, attorney docket no. 25791.93, filed on 4/12/02, (68) U.S. patent application serial no. 10/331,718, attorney docket no. 25791.94, filed on 12/30/02, which is a divisional U.S. patent application serial no. 09/679,906, filed on 10/5/00, attorney docket no. 25791.37.02, which claims priority from provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (69) PCT application US 03/04837, filed on 2/29/03, attorney docket no. 25791.95.02, which claims priority from U.S. provisional patent application serial no. 60/363,829, attorney docket no. 25791.95, filed on 3/13/02, (70) U.S. patent application serial no. 10/261,927, attorney docket no. 25791.97, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (71) U.S. patent application serial no. 10/262,008, attorney docket no. 25791.98, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (72) U.S. patent application serial no. 10/261,925, attorney docket no. 25791.99, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (73) U.S. patent application serial no. 10/199,524, attorney docket no. 25791.100, filed on 7/19/02, which is a continuation of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (74) PCT application US 03/10144, filed on 3/28/03, attorney docket no. 25791.101.02, which claims priority from U.S. provisional patent application serial no. 60/372,632, attorney docket no. 25791.101, filed on

4/15/02, (75) U.S. provisional patent application serial no. 60/412,542, attorney docket no. 25791.102, filed on 9/20/02, (76) PCT application US 03/14153, filed on 5/6/03, attorney docket no. 25791.104.02, which claims priority from U.S. provisional patent application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/02, (77) PCT application US 03/19993, filed on 6/24/03, attorney docket no. 25791.106.02, which claims priority from U.S. provisional patent application serial no. 60/397,284, attorney docket no. 25791.106, filed on 7/19/02, (78) PCT application US 03/13787, filed on 5/5/03, attorney docket no. 25791.107.02, which claims priority from U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/02, (79) PCT application US 03/18530, filed on 6/11/03, attorney docket no. 25791.108.02, which claims priority from U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/02, (80) PCT application US 03/20694, filed on 7/1/03, attorney docket no. 25791.110.02, which claims priority from U.S. provisional patent application serial no. 60/398,061, attorney docket no. 25791.110, filed on 7/24/02, (81) PCT application US 03/20870, filed on 7/2/03, attorney docket no. 25791.111.02, which claims priority from U.S. provisional patent application serial no. 60/399,240, attorney docket no. 25791.111, filed on 7/29/02, (82) U.S. provisional patent application serial no. 60/412,487, attorney docket no. 25791.112, filed on 9/20/02, (83) U.S. provisional patent application serial no. 60/412,488, attorney docket no. 25791.114, filed on 9/20/02, (84) U.S. patent application serial no. 10/280,356, attorney docket no. 25791.115, filed on 10/25/02, which is a continuation of U.S. patent number 6,470,966, which was filed as patent application serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (85) U.S. provisional patent application serial no. 60/412,177, attorney docket no. 25791.117, filed on 9/20/02, (86) U.S. provisional patent application serial no. 60/412,653, attorney docket no. 25791.118, filed on 9/20/02, (87) U.S. provisional patent application serial no. 60/405,610, attorney docket no. 25791.119, filed on 8/23/02, (88) U.S. provisional patent application serial no. 60/405,394, attorney docket no. 25791.120, filed on 8/23/02, (89) U.S. provisional patent application serial no. 60/412,544, attorney docket no. 25791.121, filed on 9/20/02, (90) PCT application PCT/US03/24779, filed on 8/8/03, attorney docket no. 25791.125.02, which claims

priority from U.S. provisional patent application serial no. 60/407,442, attorney docket no. 25791.125, filed on 8/30/02, (91) U.S. provisional patent application serial no. 60/423,363, attorney docket no. 25791.126, filed on 12/10/02, (92) U.S. provisional patent application serial no. 60/412,196, attorney docket no. 25791.127, filed on 5 9/20/02, (93) U.S. provisional patent application serial no. 60/412,187, attorney docket no. 25791.128, filed on 9/20/02, (94) U.S. provisional patent application serial no. 60/412,371, attorney docket no. 25791.129, filed on 9/20/02, (95) U.S. patent application serial no. 10/382,325, attorney docket no. 25791.145, filed on 3/5/03, which is a continuation of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, 10 which claims priority from provisional application 60/137,998, filed on 6/7/99, (96) U.S. patent application serial no. 10/624,842, attorney docket no. 25791.151, filed on 7/22/03, which is a divisional of U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims priority from provisional application 60/119,611, filed on 2/11/99, (97) U.S. provisional patent application serial 15 no. 60/431,184, attorney docket no. 25791.157, filed on 12/5/02, (98) U.S. provisional patent application serial no. 60/448,526, attorney docket no. 25791.185, filed on 2/18/03, (99) U.S. provisional patent application serial no. 60/461,539, attorney docket no. 25791.186, filed on 4/9/03, (100) U.S. provisional patent application serial no. 20 60/462,750, attorney docket no. 25791.193, filed on 4/14/03, (101) U.S. provisional patent application serial no. 60/436,106, attorney docket no. 25791.200, filed on 12/23/02, (102) U.S. provisional patent application serial no. 60/442,942, attorney docket no. 25791.213, filed on 1/27/03, (103) U.S. provisional patent application serial no. 60/442,938, attorney docket no. 25791.225, filed on 1/27/03, (104) U.S. provisional patent application serial no. 60/418,687, attorney docket no. 25791.228, filed on 25 4/18/03, (105) U.S. provisional patent application serial no. 60/454,896, attorney docket no. 25791.236, filed on 3/14/03, (106) U.S. provisional patent application serial no. 60/450,504, attorney docket no. 25791.238, filed on 2/26/03, (107) U.S. provisional patent application serial no. 60/451,152, attorney docket no. 25791.239, filed on 3/9/03, (108) U.S. provisional patent application serial no. 60/455,124, attorney docket no. 30 25791.241, filed on 3/17/03, (109) U.S. provisional patent application serial no. 60/453,678, attorney docket no. 25791.253, filed on 3/11/03, (110) U.S. patent application serial no. 10/421,682, attorney docket no. 25791.256, filed on 4/23/03, which is a continuation of U.S. patent application serial no. 09/523,468, attorney docket

no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (111) U.S. provisional patent application serial no. 60/457,965, attorney docket no. 25791.260, filed on 3/27/03, (112) U.S. provisional patent application serial no. 60/455,718, attorney docket no. 25791.262, filed on 3/18/03, (113) U.S. patent number 6,550,821, which was filed as patent application serial no. 09/811,734, filed on 3/19/01, (114) U.S. patent application serial no. 10/436,467, attorney docket no. 25791.268, filed on 5/12/03, which is a continuation of U.S. patent number 6,604,763, which was filed as application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, which claims priority from provisional application 60/131,106, filed on 4/26/99, (115) U.S. provisional patent application serial no. 60/459,776, attorney docket no. 25791.270, filed on 4/2/03, (116) U.S. provisional patent application serial no. 60/461,094, attorney docket no. 25791.272, filed on 4/8/03, (117) U.S. provisional patent application serial no. 60/461,038, attorney docket no. 25791.273, filed on 4/7/03, (118) U.S. provisional patent application serial no. 60/463,586, attorney docket no. 25791.277, filed on 4/17/03, (119) U.S. provisional patent application serial no. 60/472,240, attorney docket no. 25791.286, filed on 5/20/03, (120) U.S. patent application serial no. 10/619,285, attorney docket no. 25791.292, filed on 7/14/03, which is a continuation-in-part of U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (121) U.S. utility patent application serial no. 10/418,688, attorney docket no. 25791.257, which was filed on 4/18/03, as a division of U.S. utility patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (122) PCT patent application serial no. _____, attorney docket no. 25791.238.02, filed on _____, (123) PCT patent application serial no. _____, attorney docket no. 25791.253.02, filed on _____, and (124) PCT patent application serial no. _____, attorney docket no. 25791.40.02, filed on _____, the disclosures of which are incorporated herein by reference.

Background of the Invention

This invention relates generally to oil and gas exploration, and in particular to forming and repairing wellbore casings to facilitate oil and gas exploration.

Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming and/or repairing wellbore casings.

20

Summary of the Invention

According to one aspect of the present invention, an apparatus for radially expanding and plastically deforming a tubular member is provided that includes a tubular support member defining a first passage, a tubular expansion cone defining a second passage coupled to the tubular support member, a fluid driven motor coupled to the tubular expansion cone comprising an inlet, and a rotary expansion device coupled to the output shaft of the fluid driven motor. The first passage is operably coupled to the second passage, and the second passage is operably coupled to the inlet of the fluid driven motor.

According to another aspect of the present invention, an apparatus for radially expanding and plastically deforming a tubular member is provided that includes a first expansion device for controllably straining the tubular member, and a second expansion device coupled to the first expansion device for controllably stressing the tubular member.

According to another aspect of the present invention, a method of radially

expanding and plastically deforming a tubular member is provided that includes controllably straining the tubular member, and then controllably stressing the tubular member.

5 According to another aspect of the present invention, an apparatus for radially expanding and plastically deforming a tubular member is provided that includes means for controllably straining the tubular member, and means for controllably stressing the tubular member after controllably straining the tubular member.

10 According to another aspect of the present invention, an apparatus for radially expanding and plastically deforming a tubular member is provided that includes a first expansion device for radially expanding the tubular member, and a second expansion device coupled to the first expansion device for further radially expanding the tubular member.

15 According to another aspect of the present invention, a method of radially expanding and plastically deforming a tubular member is provided that includes radially expanding a portion of the tubular member, and then further radially expanding the portion of the tubular member.

20 According to another aspect of the present invention, a system for radially expanding and plastically deforming a tubular member is provided that includes means for radially expanding a portion of the tubular member, and means for then further radially expanding the portion of the tubular member.

According to another aspect of the present invention, a method of radially expanding and plastically deforming a tubular member is provided that includes controllably stressing the tubular member; and then controllably straining the tubular member.

25 According to another aspect of the present invention, an apparatus for radially expanding and plastically deforming a tubular member is provided that includes means for controllably stressing the tubular member; and means for controllably straining the tubular member after controllably stressing the tubular member.

Brief Description of the Drawings

30 Fig. 1 is a fragmentary cross sectional illustration of an exemplary embodiment of an apparatus for radially expanding a tubular member.

Detailed Description of the Illustrative Embodiments

Referring to Fig. 1, an exemplary embodiment of an apparatus 100 for radially expanding a tubular member includes a tubular support member 102 that defines a

passage 102a. An end of an expansion mandrel 104 that defines a passage 104a, a chamber 104b, and a passage 104c is coupled to an end of the tubular support member 102 that includes a tapered outer surface 104d.

5 A conventional mud motor 106 is positioned within the chamber 104b of the mandrel 104 that includes an rotatable output shaft 106a that extends out of the mandrel. In an exemplary embodiment, the inlet of the mud motor 106 is fluidically coupled to the passage 104a of the mandrel, and the outlet of the mud motor is fluidically coupled to the passage 104c of the mandrel. In this manner, the mud motor 106 may be operated to rotate the shaft 106a upon pumping fluidic materials into and through the mud motor.

10 A conventional rotary expansion tool 108 is coupled to an end of the shaft 106a that may be any number of conventional commercially available rotary expansion devices such as, for example, the rotary expansion devices commercially available from Weatherford International or as described in one or more of the following: U.S. 6,457,532 and/or WO 02/081863 A1, the disclosures of which are incorporated herein

15 by reference. In an exemplary embodiment, the rotary expansion tool 108 includes one or more circumferentially and/or axially spaced apart roller expansion elements 108a.

The mandrel 104, the mud motor 106, and the rotary expansion tool 108 are housed within a tubular launcher assembly 110 that includes a shoe 110a, a tubular section 110b, and a tapered tubular section 110c. In an exemplary embodiment, the

20 tubular section 110b of the tubular launcher assembly 110 mates with the mandrel 104 and the rotary expansion tool 108. An end of an expandable tubular 112 is coupled to the tapered tubular section 110c of the launcher assembly 110. In an exemplary embodiment, one or more cup seals 114 are coupled to the exterior of the tubular support 102 for sealingly engaging the interior surface of the expandable tubular

25 member 112.

In an exemplary embodiment, the apparatus is initially positioned within a borehole 116 that traverses a subterranean formation 118. Fluidic materials 120 are then injected into the apparatus 100 through the passages, 102a and 104a. The fluidic materials 120 are then conveyed into and through the mud motor 106 and out of the

30 mandrel 104 through the passage 104c. As a result, the mud motor 106 is operated to thereby rotate the shaft 106a and the rotary expansion tool 108. Also, as a result, the interior portion of the launcher 110 below the mandrel 104 is pressurized thereby causing the mandrel, mud motor 106, and the rotary expansion tool 108 to be displaced upwardly relative to the launcher 110.

The upward displacement of the mandrel 104, mud motor 106, and rotary expansion tool 108 then radially expands and plastically deforms at least the tubular section 110b and the tapered tubular section 110c of the launcher 110 and the expandable tubular member 112. In an exemplary embodiment, the tapered surface
5 104d of the expansion mandrel 104 provides the majority of the radial expansion and plastic deformation of the tapered tubular section 110c of the launcher 110 and the expandable tubular member 112. In an exemplary embodiment, the outside diameter of the rotary expansion tool 108 is adjustable and thereby permits the rotary expansion tool 108 to radially expand and plastically deform the expandable tubular member 112
10 into intimate contact with the walls of the borehole 114. As a result, the formation surrounding the expandable tubular member 112 may be compressed and, after the completion of the radial expansion and plastic deformation of the expandable tubular member, held in compression. In an exemplary embodiment, during the operation of the apparatus 100, the expansion mandrel 104 applies radial forces to contiguous
15 circumferential interior surfaces of the tubular launcher assembly 110 and/or the expandable tubular member 112, and the rotary expansion tool 108 applies radial forces to discrete noncontiguous interior surfaces of the tubular launcher assembly and/or the expandable tubular member.

During the operation of the apparatus 100, in an exemplary embodiment, the
20 expansion mandrel 104 provides a strain controlled radial expansion process, and the rotary expansion tool 108 provides a stress controlled radial expansion process. For example, the final inside diameter of the expandable tubular member 112 provided by operation of the expansion mandrel 104 is controlled by the shape and geometry of the expansion mandrel and should be constant. However, the final inside diameter of the
25 expandable tubular member provided by operation of the rotary expansion tool 108 may, or may not, be constant depending upon the shape of the wellbore 116. In particular, the amount of strain of the expandable tubular member 112 provided by the rotary expansion tool 108 is not controlled. Rather, the amount of stress applied to the expandable tubular member 112 by the rotary expansion tool 108 is controlled by
30 controlling the compliance of the roller expansion elements 108a. Consequently, in an exemplary embodiment, the operation of the rotary expansion tool 108 will cause the outside diameter of the expandable tubular member 112 to engage and thereby match the inside diametrical shape of the wellbore 116. A strain controlled radial expansion process is typically capable of providing more radial expansion and plastic deformation

than a stress controlled radial expansion process. However, a stress controlled radial expansion process is typically more capable of expanding a tubular member into engagement with an irregularly shaped wellbore 116. Consequently, the combination of a strain controlled expansion process with a stress controlled expansion process provides the benefits of both in one radial expansion process.

In several alternative embodiments, during the operation of the apparatus 100, the tubular support member 102, mandrel 104, and/or mud motor 106 are also rotated during the radial expansion and plastic deformation of the expandable tubular member 112. In several alternative embodiments, during the operation of the apparatus 100, the rotary expansion tool 108 is not rotated relative to the mandrel 104.

In an alternative embodiment, the expansion mandrel 104 is pulled upwardly relative to the tubular member 112 in combination with, or in substitution for, the injection of the fluidic material 120 during at least a portion of the radial expansion and plastic deformation of the tubular member.

In several exemplary embodiments, the interface between the expansion mandrel 104 and the tubular launcher assembly 110 and/or the expandable tubular member 112 is not fluid tight. As a result, the annulus defined between the cup seals 114 and the expansion mandrel 104 within the expandable tubular member 112 is pressurized such that the resulting axial force applied to the cup seals pulls the expansion mandrel 104 and the rotary expansion device 108 through the tubular launcher assembly 110 and/or the expandable tubular member 112.

In several alternative embodiments, the order and/or orientation of the expansion mandrel 104 and/or rotary expansion tool 108 may be reversed.

In several alternative embodiments, a conventional hydro-forming device may be substituted for, or used in addition to, the expansion mandrel 104.

In several alternative embodiments, the expansion mandrel 104 and/or the rotary expansion tool 108 are adjustable in size.

In several alternative embodiments, a conventional rotary expansion tool such as, for example, as described in U.S. 6,457,532 and/or WO 02/081863 A1, the disclosures of which are incorporated herein by reference, or any one of the commercially available rotary expansion tools available from Weatherford International, Inc. may be substituted for, or used in combination with, the expansion mandrel 104.

In several alternative embodiments, the exemplary embodiments of Fig. 1 are implemented using the methods and/or apparatus disclosed one or more of the

following: (1) U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, which claims priority from provisional application 60/121,702, filed on 2/25/99, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims priority from provisional application 60/119,611, filed on 2/11/99, (4) U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (5) U.S. patent application serial no. 10/169,434, attorney docket no. 25791.10.04, filed on 7/1/02, which claims priority from provisional application 60/183,546, filed on 2/18/00, (6) U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (7) U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (8) U.S. patent number 6,575,240, which was filed as patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, which claims priority from provisional application 60/121,907, filed on 2/26/99, (9) U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (10) U.S. patent application serial no. 09/981,916, attorney docket no. 25791.18, filed on 10/18/01 as a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (11) U.S. patent number 6,604,763, which was filed as application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, which claims priority from provisional application 60/131,106, filed on 4/26/99, (12) U.S. patent application serial no. 10/030,593, attorney docket no. 25791.25.08, filed on 1/8/02, which claims priority from provisional application 60/146,203, filed on 7/29/99, (13) U.S. provisional patent application serial no. 60/143,039, attorney docket no. 25791.26, filed on 7/9/99, (14) U.S. patent application serial no. 10/111,982, attorney docket no. 25791.27.08, filed on

4/30/02, which claims priority from provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (15) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (16) U.S. provisional patent application serial no. 60/438,828, attorney docket no. 5 25791.31, filed on 1/9/03, (17) U.S. patent number 6,564,875, which was filed as application serial no. 09/679,907, attorney docket no. 25791.34.02, on 10/5/00, which claims priority from provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (18) U.S. patent application serial no. 10/089,419, filed on 3/27/02, attorney docket no. 25791.36.03, which claims priority from provisional 10 patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (19) U.S. patent application serial no. 09/679,906, filed on 10/5/00, attorney docket no. 25791.37.02, which claims priority from provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (20) U.S. patent application serial no. 10/303,992, filed on 11/22/02, attorney docket 15 no. 25791.38.07, which claims priority from provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (21) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (22) U.S. provisional patent application serial no. 60/455,051, attorney docket no. 25791.40, filed on 3/14/03, (23) PCT application US02/2477, filed on 20 6/26/02, attorney docket no. 25791.44.02, which claims priority from U.S. provisional patent application serial no. 60/303,711, attorney docket no. 25791.44, filed on 7/6/01, (24) U.S. patent application serial no. 10/311,412, filed on 12/12/02, attorney docket no. 25791.45.07, which claims priority from provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (25) U.S. patent 25 application serial no. 10/, filed on 12/18/02, attorney docket no. 25791.46.07, which claims priority from provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (26) U.S. patent application serial no. 10/322,947, filed on 1/22/03, attorney docket no. 25791.47.03, which claims priority from provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed 30 on 9/18/2000, (27) U.S. patent application serial no. 10/406,648, filed on 3/31/03, attorney docket no. 25791.48.06, which claims priority from provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (28) PCT application US02/04353, filed on 2/14/02, attorney docket no. 25791.50.02, which claims priority from U.S. provisional patent application serial no. 60/270,007,

attorney docket no. 25791.50, filed on 2/20/2001, (29) U.S. patent application serial no. 10/465,835, filed on 6/13/03, attorney docket no. 25791.51.06, which claims priority from provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (30) U.S. patent application serial no. 10/465,831, filed on 6/13/03, attorney docket no. 25791.52.06, which claims priority from U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (31) U.S. provisional patent application serial no. 60/452,303, filed on 3/5/03, attorney docket no. 25791.53, (32) U.S. patent number 6,470,966, which was filed as patent application serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (33) U.S. patent number 6,561,227, which was filed as patent application serial number 09/852,026, filed on 5/9/01, attorney docket no. 25791.56, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (34) U.S. patent application serial number 09/852,027, filed on 5/9/01, attorney docket no. 25791.57, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (35) PCT Application US02/25608, attorney docket no. 25791.58.02, filed on 8/13/02, which claims priority from provisional application 60/318,021, filed on 9/7/01, attorney docket no. 25791.58, (36) PCT Application US02/24399, attorney docket no. 25791.59.02, filed on 8/1/02, which claims priority from U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (37) PCT Application US02/29856, attorney docket no. 25791.60.02, filed on 9/19/02, which claims priority from U.S. provisional patent application serial no. 60/326,886, attorney docket no. 25791.60, filed on 10/3/2001, (38) PCT Application US02/20256, attorney docket no. 25791.61.02, filed on 6/26/02, which claims priority from U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (39) U.S. patent application serial no. 09/962,469, filed on 9/25/01, attorney docket no. 25791.62, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority

from provisional application 60/124,042, filed on 3/11/99, (40) U.S. patent application serial no. 09/962,470, filed on 9/25/01, attorney docket no. 25791.63, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application

5 60/124,042, filed on 3/11/99, (41) U.S. patent application serial no. 09/962,471, filed on 9/25/01, attorney docket no. 25791.64, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (42) U.S. patent application serial no. 09/962,467, filed on 9/25/01, attorney docket no.

10 25791.65, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (43) U.S. patent application serial no. 09/962,468, filed on 9/25/01, attorney docket no. 25791.66, which is a divisional of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on

15 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (44) PCT application US 02/25727, filed on 8/14/02, attorney docket no. 25791.67.03, which claims priority from U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, and U.S. provisional patent application serial no. 60/318,386, attorney docket no. 25791.67.02, filed on

20 9/10/2001, (45) PCT application US 02/39425, filed on 12/10/02, attorney docket no. 25791.68.02, which claims priority from U.S. provisional patent application serial no. 60/343,674 , attorney docket no. 25791.68, filed on 12/27/2001, (46) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed

25 as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (47) U.S. utility patent application serial no. 10/516,467, attorney docket no. 25791.70, filed on 12/10/01, which is a continuation application of U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed

30 on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (48) PCT application US 03/00609, filed on 1/9/03, attorney docket no. 25791.71.02, which claims priority from U.S. provisional patent

application serial no. 60/357,372 , attorney docket no. 25791.71, filed on 2/15/02, (49)
 U.S. patent application serial no. 10/074,703, attorney docket no. 25791.74, filed on
 2/12/02, which is a divisional of U.S. patent number 6,568,471, which was filed as
 patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on
 5 2/24/2000, which claims priority from provisional application 60/121,841, filed on
 2/26/99, (50) U.S. patent application serial no. 10/074,244, attorney docket no.
 25791.75, filed on 2/12/02, which is a divisional of U.S. patent number 6,568,471,
 which was filed as patent application serial no. 09/512,895, attorney docket no.
 25791.12.02, filed on 2/24/2000, which claims priority from provisional application
 10 60/121,841, filed on 2/26/99, (51) U.S. patent application serial no. 10/076,660,
 attorney docket no. 25791.76, filed on 2/15/02, which is a divisional of U.S. patent
 number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney
 docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional
 application 60/121,841, filed on 2/26/99, (52) U.S. patent application serial no.
 15 10/076,661, attorney docket no. 25791.77, filed on 2/15/02, which is a divisional of
 U.S. patent number 6,568,471, which was filed as patent application serial no.
 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority
 from provisional application 60/121,841, filed on 2/26/99, (53) U.S. patent application
 serial no. 10/076,659, attorney docket no. 25791.78, filed on 2/15/02, which is a
 20 divisional of U.S. patent number 6,568,471, which was filed as patent application serial
 no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims
 priority from provisional application 60/121,841, filed on 2/26/99, (54) U.S. patent
 application serial no. 10/078,928, attorney docket no. 25791.79, filed on 2/20/02,
 which is a divisional of U.S. patent number 6,568,471, which was filed as patent
 25 application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000,
 which claims priority from provisional application 60/121,841, filed on 2/26/99, (55) U.S.
 patent application serial no. 10/078,922, attorney docket no. 25791.80, filed on
 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as
 patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on
 30 2/24/2000, which claims priority from provisional application 60/121,841, filed on
 2/26/99, (56) U.S. patent application serial no. 10/078,921, attorney docket no.
 25791.81, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471,
 which was filed as patent application serial no. 09/512,895, attorney docket no.
 25791.12.02, filed on 2/24/2000, which claims priority from provisional application

60/121,841, filed on 2/26/99, (57) U.S. patent application serial no. 10/261,928, attorney docket no. 25791.82, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (58) U.S. patent application serial no. 10/079,276, attorney docket no. 25791.83, filed on 2/20/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (59) U.S. patent application serial no. 10/262,009, attorney docket no. 25791.84, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (60) U.S. patent application serial no. 10/092,481, attorney docket no. 25791.85, filed on 3/7/02, which is a divisional of U.S. patent number 6,568,471, which was filed as patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, which claims priority from provisional application 60/121,841, filed on 2/26/99, (61) U.S. patent application serial no. 10/261,926, attorney docket no. 25791.86, filed on 10/1/02, which is a divisional of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (62) PCT application US 02/36157, filed on 11/12/02, attorney docket no. 25791.87.02, which claims priority from U.S. provisional patent application serial no. 60/338,996, attorney docket no. 25791.87, filed on 11/12/01, (63) PCT application US 02/36267, filed on 11/12/02, attorney docket no. 25791.88.02, which claims priority from U.S. provisional patent application serial no. 60/339,013, attorney docket no. 25791.88, filed on 11/12/01, (64) PCT application US 03/11765, filed on 4/16/03, attorney docket no. 25791.89.02, which claims priority from U.S. provisional patent application serial no. 60/383,917, attorney docket no. 25791.89, filed on 5/29/02, (65) PCT application US 03/15020, filed on 5/12/03, attorney docket no. 25791.90.02, which claims priority from U.S. provisional patent application serial no. 60/391,703, attorney docket no. 25791.90, filed on 6/26/02, (66) PCT application US 02/39418, filed on 12/10/02, attorney docket no. 25791.92.02, which claims priority from U.S. provisional patent application serial no. 60/346,309, attorney docket no. 25791.92, filed on 1/7/02, (67)

PCT application US 03/06544, filed on 3/4/03, attorney docket no. 25791.93.02, which
 claims priority from U.S. provisional patent application serial no. 60/372,048, attorney
 docket no. 25791.93, filed on 4/12/02, (68) U.S. patent application serial no.
 10/331,718, attorney docket no. 25791.94, filed on 12/30/02, which is a divisional U.S.
 5 patent application serial no. 09/679,906, filed on 10/5/00, attorney docket no.
 25791.37.02, which claims priority from provisional patent application serial no.
 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (69) PCT application
 US 03/04837, filed on 2/29/03, attorney docket no. 25791.95.02, which claims priority
 from U.S. provisional patent application serial no. 60/363,829, attorney docket no.
 10 25791.95, filed on 3/13/02, (70) U.S. patent application serial no. 10/261,927, attorney
 docket no. 25791.97, filed on 10/1/02, which is a divisional of U.S. patent number
 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket
 no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application
 60/137,998, filed on 6/7/99, (71) U.S. patent application serial no. 10/262,008, attorney
 15 docket no. 25791.98, filed on 10/1/02, which is a divisional of U.S. patent number
 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket
 no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application
 60/137,998, filed on 6/7/99, (72) U.S. patent application serial no. 10/261,925, attorney
 docket no. 25791.99, filed on 10/1/02, which is a divisional of U.S. patent number
 20 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket
 no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application
 60/137,998, filed on 6/7/99, (73) U.S. patent application serial no. 10/199,524, attorney
 docket no. 25791.100, filed on 7/19/02, which is a continuation of U.S. Patent Number
 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney
 25 docket no. 25791.03.02, filed on 12/3/1999, which claims priority from provisional
 application 60/111,293, filed on 12/7/98, (74) PCT application US 03/10144, filed on
 3/28/03, attorney docket no. 25791.101.02, which claims priority from U.S. provisional
 patent application serial no. 60/372,632, attorney docket no. 25791.101, filed on
 4/15/02, (75) U.S. provisional patent application serial no. 60/412,542, attorney docket
 30 no. 25791.102, filed on 9/20/02, (76) PCT application US 03/14153, filed on 5/6/03,
 attorney docket no. 25791.104.02, which claims priority from U.S. provisional patent
 application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/02, (77)
 PCT application US 03/19993, filed on 6/24/03, attorney docket no. 25791.106.02,
 which claims priority from U.S. provisional patent application serial no. 60/397,284,

attorney docket no. 25791.106, filed on 7/19/02, (78) PCT application US 03/13787, filed on 5/5/03, attorney docket no. 25791.107.02, which claims priority from U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/02, (79) PCT application US 03/18530, filed on 6/11/03, attorney docket

5 no. 25791.108.02, which claims priority from U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/02, (80) PCT application US 03/20694, filed on 7/1/03, attorney docket no. 25791.110.02, which claims priority from U.S. provisional patent application serial no. 60/398,061, attorney docket no. 25791.110, filed on 7/24/02, (81) PCT application US 03/20870, filed on 7/2/03,

10 attorney docket no. 25791.111.02, which claims priority from U.S. provisional patent application serial no. 60/399,240, attorney docket no. 25791.111, filed on 7/29/02, (82) U.S. provisional patent application serial no. 60/412,487, attorney docket no. 25791.112, filed on 9/20/02, (83) U.S. provisional patent application serial no. 60/412,488, attorney docket no. 25791.114, filed on 9/20/02, (84) U.S. patent

15 application serial no. 10/280,356, attorney docket no. 25791.115, filed on 10/25/02, which is a continuation of U.S. patent number 6,470,966, which was filed as patent application serial number 09/850,093, filed on 5/7/01, attorney docket no. 25791.55, as a divisional application of U.S. Patent Number 6,497,289, which was filed as U.S. Patent Application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on

20 12/3/1999, which claims priority from provisional application 60/111,293, filed on 12/7/98, (85) U.S. provisional patent application serial no. 60/412,177, attorney docket no. 25791.117, filed on 9/20/02, (86) U.S. provisional patent application serial no. 60/412,653, attorney docket no. 25791.118, filed on 9/20/02, (87) U.S. provisional

25 patent application serial no. 60/405,610, attorney docket no. 25791.119, filed on 8/23/02, (88) U.S. provisional patent application serial no. 60/405,394, attorney docket no. 25791.120, filed on 8/23/02, (89) U.S. provisional patent application serial no. 60/412,544, attorney docket no. 25791.121, filed on 9/20/02, (90) PCT application PCT/US03/24779, filed on 8/8/03, attorney docket no. 25791.125.02, which claims

30 priority from U.S. provisional patent application serial no. 60/407,442, attorney docket no. 25791.125, filed on 8/30/02, (91) U.S. provisional patent application serial no. 60/423,363, attorney docket no. 25791.126, filed on 12/10/02, (92) U.S. provisional patent application serial no. 60/412,196, attorney docket no. 25791.127, filed on 9/20/02, (93) U.S. provisional patent application serial no. 60/412,187, attorney docket no. 25791.128, filed on 9/20/02, (94) U.S. provisional patent application serial no.

60/412,371, attorney docket no. 25791.129, filed on 9/20/02, (95) U.S. patent application serial no. 10/382,325, attorney docket no. 25791.145, filed on 3/5/03, which is a continuation of U.S. patent number 6,557,640, which was filed as patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, which claims priority from provisional application 60/137,998, filed on 6/7/99, (96) U.S. patent application serial no. 10/624,842, attorney docket no. 25791.151, filed on 7/22/03, which is a divisional of U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, which claims priority from provisional application 60/119,611, filed on 2/11/99, (97) U.S. provisional patent application serial no. 60/431,184, attorney docket no. 25791.157, filed on 12/5/02, (98) U.S. provisional patent application serial no. 60/448,526, attorney docket no. 25791.185, filed on 2/18/03, (99) U.S. provisional patent application serial no. 60/461,539, attorney docket no. 25791.186, filed on 4/9/03, (100) U.S. provisional patent application serial no. 60/462,750, attorney docket no. 25791.193, filed on 4/14/03, (101) U.S. provisional patent application serial no. 60/436,106, attorney docket no. 25791.200, filed on 12/23/02, (102) U.S. provisional patent application serial no. 60/442,942, attorney docket no. 25791.213, filed on 1/27/03, (103) U.S. provisional patent application serial no. 60/442,938, attorney docket no. 25791.225, filed on 1/27/03, (104) U.S. provisional patent application serial no. 60/418,687, attorney docket no. 25791.228, filed on 4/18/03, (105) U.S. provisional patent application serial no. 60/454,896, attorney docket no. 25791.236, filed on 3/14/03, (106) U.S. provisional patent application serial no. 60/450,504, attorney docket no. 25791.238, filed on 2/26/03, (107) U.S. provisional patent application serial no. 60/451,152, attorney docket no. 25791.239, filed on 3/9/03, (108) U.S. provisional patent application serial no. 60/455,124, attorney docket no. 25791.241, filed on 3/17/03, (109) U.S. provisional patent application serial no. 60/453,678, attorney docket no. 25791.253, filed on 3/11/03, (110) U.S. patent application serial no. 10/421,682, attorney docket no. 25791.256, filed on 4/23/03, which is a continuation of U.S. patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (111) U.S. provisional patent application serial no. 60/457,965, attorney docket no. 25791.260, filed on 3/27/03, (112) U.S. provisional patent application serial no. 60/455,718, attorney docket no. 25791.262, filed on 3/18/03, (113) U.S. patent number 6,550,821, which was filed as patent application serial no. 09/811,734, filed on 3/19/01, (114) U.S. patent application serial no.

10/436,467, attorney docket no. 25791.268, filed on 5/12/03, which is a continuation of U.S. patent number 6,604,763, which was filed as application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, which claims priority from provisional application 60/131,106, filed on 4/26/99, (115) U.S. provisional patent application serial no. 60/459,776, attorney docket no. 25791.270, filed on 4/2/03, (116) U.S. provisional patent application serial no. 60/461,094, attorney docket no. 25791.272, filed on 4/8/03, (117) U.S. provisional patent application serial no. 60/461,038, attorney docket no. 25791.273, filed on 4/7/03, (118) U.S. provisional patent application serial no. 60/463,586, attorney docket no. 25791.277, filed on 4/17/03, (119) U.S. provisional patent application serial no. 60/472,240, attorney docket no. 25791.286, filed on 5/20/03, (120) U.S. patent application serial no. 10/619,285, attorney docket no. 25791.292, filed on 7/14/03, which is a continuation-in-part of U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, which is a continuation-in-part application of U.S. patent no. 6,328,113, which was filed as U.S. Patent Application serial number 09/440,338, attorney docket number 25791.9.02, filed on 11/15/99, which claims priority from provisional application 60/108,558, filed on 11/16/98, (121) U.S. utility patent application serial no. 10/418,688, attorney docket no. 25791.257, which was filed on 4/18/03, as a division of U.S. utility patent application serial no. 09/523,468, attorney docket no. 25791.11.02, filed on 3/10/2000, which claims priority from provisional application 60/124,042, filed on 3/11/99, (122) PCT patent application serial no. PCT/US04/_____, attorney docket no. 25791.238.02, filed on 2/26/04, (123) PCT patent application serial no. PCT/US04/_____, attorney docket no. 25791.253.02, filed on 3/11/04, and (124) PCT patent application serial no. PCT/US04/_____, attorney docket no. 25791.40.02, filed on 3/15/04, the disclosures of which are incorporated herein by reference.

An apparatus for radially expanding and plastically deforming a tubular member has been described that includes a tubular support member defining a first passage, a tubular expansion cone defining a second passage coupled to the tubular support member, a fluid driven motor coupled to the tubular expansion cone comprising an inlet, and a rotary expansion device coupled to the output shaft of the fluid driven motor. The first passage is operably coupled to the second passage, and the second passage is operably coupled to the inlet of the fluid driven motor.

An apparatus for radially expanding and plastically deforming a tubular member

has been described that includes a first expansion device for controllably straining the tubular member, and a second expansion device coupled to the first expansion device for controllably stressing the tubular member. In an exemplary embodiment, the apparatus further includes a motor coupled to the first expansion device for rotating the
5 second expansion device relative to the first expansion device.

A method of radially expanding and plastically deforming a tubular member has been described that includes controllably straining the tubular member, and then controllably stressing the tubular member.

An apparatus for radially expanding and plastically deforming a tubular member
10 has been described that includes means for controllably straining the tubular member, and means for controllably stressing the tubular member after controllably straining the tubular member.

An apparatus for radially expanding and plastically deforming a tubular member has been described that includes a first expansion device for radially expanding the
15 tubular member, and a second expansion device coupled to the first expansion device for further radially expanding the tubular member. In an exemplary embodiment, the apparatus further includes a motor coupled to the first expansion device for rotating the second expansion device relative to the first expansion device.

A method of radially expanding and plastically deforming a tubular member has
20 been described that includes radially expanding a portion of the tubular member, and then further radially expanding the portion of the tubular member. In an exemplary embodiment, radially expanding the portion of the tubular member includes applying forces to a continuous circumferential portion of the interior surface of the tubular member. In an exemplary embodiment, further radially expanding the portion of the
25 tubular member includes applying forces to one or more discrete portions of the interior surface of the tubular member.

A system for radially expanding and plastically deforming a tubular member has been described that includes means for radially expanding a portion of the tubular member, and means for then further radially expanding the portion of the tubular
30 member. In an exemplary embodiment, the means for radially expanding the portion of the tubular member includes means for applying forces to a continuous circumferential portion of the interior surface of the tubular member. In an exemplary embodiment, the means for further radially expanding the portion of the tubular member includes means for applying forces to one or more discrete portions of the interior surface of the tubular

member.

A method of radially expanding and plastically deforming a tubular member has been described that includes controllably stressing the tubular member; and then controllably straining the tubular member.

5 An apparatus for radially expanding and plastically deforming a tubular member has been described that includes means for controllably stressing the tubular member; and means for controllably straining the tubular member after controllably stressing the tubular member.

10 It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the teachings of the present illustrative embodiments may be used to provide a wellbore casing, a pipeline, or a structural support. Furthermore, the teachings of the present disclosure may incorporate one or more features or operational aspects of conventional hydro-forming tools.

15 Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

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Claims

1. An apparatus for radially expanding and plastically deforming a tubular member, comprising:
 - a first expansion device for radially expanding the tubular member;
 - 5 a second expansion device coupled to the first expansion device for further radially expanding the tubular member; and
 - a motor coupled to the first expansion device for at least one of:
 - rotating the second expansion device relative to the first expansion device, and
 - displacing the second expansion device relative to the first expansion device.
- 10 2. The apparatus of claim 1, further comprising:
 - a tubular support defining a first passage;
 - wherein the first expansion device comprises a tubular expansion cone defining a second passage coupled to the tubular support member;
 - 15 wherein the motor comprises a fluid driven motor coupled to the tubular expansion cone comprising an inlet;
 - wherein the second expansion device comprises a rotary expansion device coupled to the output shaft of the fluid driven motor;
 - wherein the first passage is fluidically coupled to the second passage; and
 - 20 wherein the second passage is operably coupled to the inlet of the fluid driven motor.
- 25 3. The apparatus of claim 1, wherein the motor is adapted to rotate the second expansion device relative to the first expansion device.
4. The apparatus of claim 1, wherein the motor is adapted to displace the second expansion device relative to the first expansion device.
- 30 5. The apparatus of claim 1, wherein the interface between the first expansion device and the tubular member is not fluid tight; and wherein the apparatus further comprises means for pulling the first expansion device through the tubular member.
6. The apparatus of claim 1, further comprising a hydroforming device for radially expanding and plastically deforming the tubular member.

7. The apparatus of claim 1, wherein at least one of the first and second expansion devices is adjustable in size.
- 5 8. The apparatus of claim 1, wherein the tubular member comprises a pipeline.
9. The apparatus of claim 1, wherein the tubular member comprises a structural support.
- 10 10. The apparatus of claim 1, further comprising a hydroforming device for radially expanding and plastically deforming the tubular member;
wherein at least one of the first and second expansion devices is adjustable in size; and
wherein the tubular member comprises at least one of a pipeline or structural
15 support.
11. A method of radially expanding and plastically deforming a tubular member, comprising:
radially expanding a portion of the tubular member; and
20 then further radially expanding the portion of the tubular member;
wherein radially expanding the portion of the tubular member comprises applying forces to a continuous circumferential portion of the interior surface of the tubular member; and
wherein further radially expanding the portion of the tubular member comprises
25 applying forces to one or more discrete portions of the interior surface of the tubular member.
12. A system for radially expanding and plastically deforming a tubular member, comprising:
30 means for radially expanding a portion of the tubular member; and
means for then further radially expanding the portion of the tubular member.
13. The system of claim 12, wherein means for radially expanding the portion of the tubular member comprises:

means for applying forces to a continuous circumferential portion of the interior surface of the tubular member.

14. The system of claim 12, wherein means for further radially expanding the
5 portion of the tubular member comprises:

means for applying forces to one or more discrete portions of the interior surface of the tubular member.

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Claims searched: 1-14

Date of search: 1 November 2006

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	11-14	US 3785193 A (Kinley) Whole document
X	11-14	US 2627891 A (Clark) Whole document
X,E	11-14	WO 2005/088070 A1 (Campo) Whole document

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X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X:

E1F

Worldwide search of patent documents classified in the following areas of the IPC

E21B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI